

PHYSICAL RESTRAINT PRODUCES RAPID ACQUISITION OF THE PIGEON'S KEY PECK

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The acquisition and maintenance of autoshaped key pecking in pigeons was studied as a function of intertrial interval. At each of six intervals, which ranged from 12 seconds to 384 seconds, four pigeons were physically restrained during training while four other pigeons were not restrained. Restrained subjects acquired key pecking faster and with less intragroup variability at each interval. The effects of restraint were specific to acquisition and were not evident in maintained responding after five postacquisition sessions.

Key words: autoshaping, physical restraint, intertrial interval, key peck, pigeons

Psychologists have long sought to provide an answer to the perennial question, "How fast can learning take place?" Unfortunately, to date, there has been more discussion than experimentation concerning this question, although it has been central to several lines of theoretical inquiry ranging from animal conditioning to human cognitive processes.

One line of inquiry has been to study those variables which affect the speed of learning. A variety of findings have identified temporal factors as exerting a strong influence upon acquisition. In animal conditioning it has been shown that acquisition, defined as the number of learning trials prior to the emergence of reliable responding, varies inversely with the duration of the intertrial interval (ITI). Acquisition is considerably faster at longer ITIs than at shorter ITIs.

For example, Terrace, Gibbon, Farrell, and Baldock (1975) studied the acquisition of the pigeon's autoshaped key peck as a function of ITIs which ranged from 10 sec to 400 sec. The effects of ITI on acquisition extended over nearly two orders of magnitude: at the shortest ITIs acquisition required 100 or more signal-food pairings, whereas at a 400-sec ITI acquisition was observed in less than 10 trials (see Gibbon, Baldock, Locurto, Gold, & Terrace, 1977, for an important extension of this work which indicates that the parameter of interest is the ratio of ITI to trial duration).

The function relating ITI to acquisition was approximated by a power function with negative slope (cf. Perkins, Beaver, Hancock, Hemmendinger, Hemmendinger, & Ricci, 1975). These results are consistent with a substantial array of observations from studies of human learning wherein the superiority of distributed trials as compared to massed trials (i.e., long versus short ITIs) has been demonstrated (e.g., Underwood, 1961).

Despite the large number of investigations of ITI effects, an accepted theoretical account has not as yet emerged. More recent studies have focused upon the greater fluctuations in the subject's sampling of the training stimulus and/or increased conditioning to uncontrolled background stimuli at short ITIs versus long ITIs (e.g., Estes, 1960; Gormezano & Moore, 1969, pp. 146-148; see also Gibbon, 1977; Rescorla & Wagner, 1972). Although the mechanism whereby ITI exerts its effect remains in doubt, these interpretations share a common prediction that altering the learning environment to reduce variability should facilitate acquisition and reduce the differences between massed and distributed practice. To date, although questions concerning the most advantageous environment are necessary to the development of a comprehensive understanding of learning, few explorations have been made of the optimal conditions under which learning may occur.

The present study sought to reduce variability and, concurrently, to influence the speed of acquisition. Our strategy stemmed from the informal observation that pigeons

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often emitted behavior early in autoshaping which may be incompatible with signal-directed pecking, such as pecking the ground in the corners of the test chamber or inserting their head in and around the site of food delivery (more extensive descriptions have been documented by Staddon & Simmelhag, 1971; see also Brown & Jenkins, 1968). Accordingly, competing behavior was minimized with a restrainer that, when inserted into a standard-sized test chamber, positioned the subject so that it faced the test panel with its head at the level of the response key. The pigeon was free to lower its head and eat from the food tray directly below the response key. At the same time the restrainer prohibited most other movements.

METHOD

Subjects

Forty-eight male White Carneaux pigeons approximately one year old were maintained at 80% of their free-feeding weights. Supplementary food (mixed grain) was provided in their home cage following each session.

Apparatus

Figure 1 shows the restrainer, free-standing (right portion of the Figure) and fitted against the test panel of a standard-sized operant test chamber. The restrainer was constructed of clear Plexiglas. The top one-third of the back of the restrainer was sloped towards the test panel at approximately a 45° angle to restrict the subject's head movements. The test chamber was constructed from a modified ice chest (80-quart capacity). The test panel included a single circular response key (Lehigh Valley, Inc.) 1 cm in diameter, centered 20.3 cm above the floor. A rectangular food-tray opening located directly below the response key was the only other piece of equipment on the test panel.

The chamber was equipped with a 15-W houselight mounted in the roof which was illuminated continuously during the session except during food-tray activation. Masking noise was continuously provided. Standard electromechanical equipment located in an adjacent room controlled all procedures. Closed-circuit television was used to monitor all subjects' behavior.

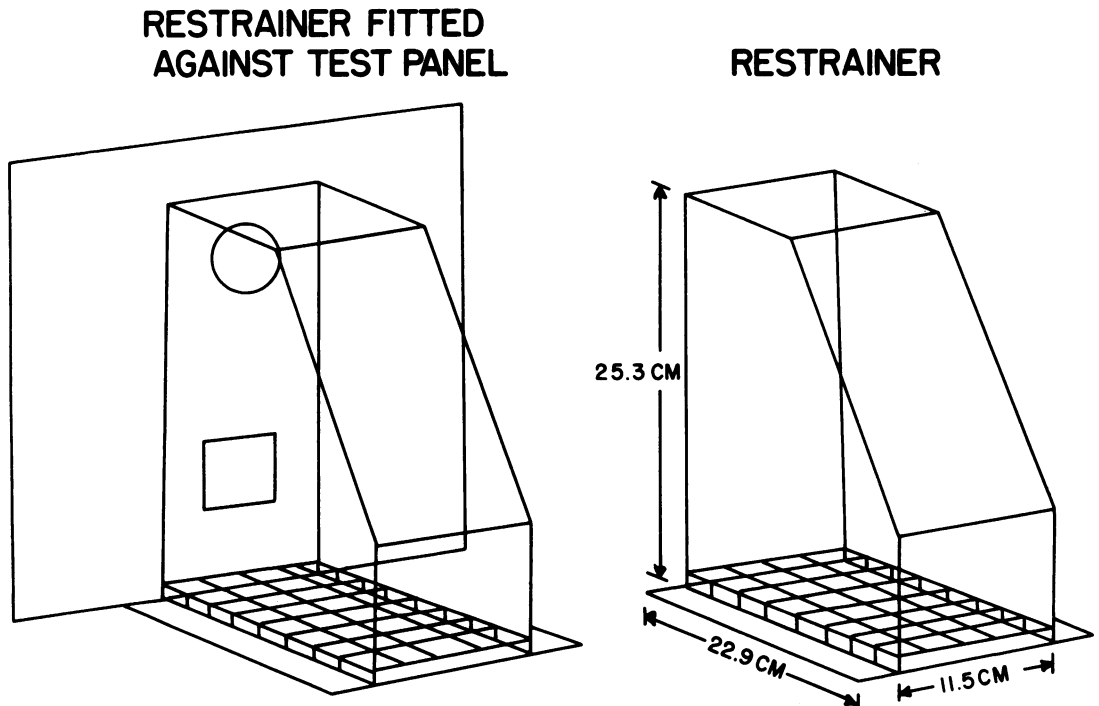


Fig. 1. Diagram of the restrainer free-standing (right) and fitted against the test panel of a standard-sized test chamber containing a response key (circle) and food aperture (square).

Procedure

All subjects were first trained to eat reliably from the food tray. A performance criterion, which all subjects were required to meet twice within four sessions, specified that each subject eat from the food tray within 3 sec of its presentation on 5 consecutive presentations. Each session consisted of a maximum of 50 food-tray presentations. For this training, interreinforcement intervals were programmed from a variable-time 96-sec schedule composed from a simple arithmetic series with an equal number of values above and below the mean value. The 24 pigeons whose key pecking was to be autoshaped without the restrainer received all their food training without the restrainer. The 24 pigeons whose key pecking was to be autoshaped in the restrainer were first trained to eat without the restrainer until they had met the criterion once. They were then given a second session in the restrainer. The restrainer had no effect on the percentage of subjects which met the eating criterion. Seventy-four percent of all subjects met the criterion in their first session. An equal percentage of these subjects (89%) met the criterion for the second time in their second session, whether this second session was with or without the restrainer.

Autoshaping began on the day following successful completion of food-tray training. Restrained and unrestrained subjects were randomly divided into groups of four subjects, a procedure which resulted in six groups within each of the two treatments. A group from each treatment was then assigned to 1 of 6 intertrial intervals which ranged from 12 sec to 384 sec.

The signal used during autoshaping was a green light (IEE projector #10M 54-Q-44B) projected onto the rear of a translucent response key for 8 sec. Following each stimulus presentation the subject was allowed access to the hopper for 5.5 sec. Sessions began with an unsignaled presentation of food for 5.5 sec after which the first ITI, which equaled the mean value for that group, was initiated. Intertrial intervals during autoshaping were constructed from the progression suggested by Fleshler and Hoffman (1962). Sessions consisted of 25 trials and were conducted daily.

To facilitate the systematic observation of all subjects' behavior prior to the establish-

ment of reliable responding, the floor of the test chamber was divided into six segments. A subject's position in one of these segments was recorded (by one of the first two authors) at trial onset, and again at the moment of reinforcer delivery. In addition, a brief description of a subject's movement and related behavior during the trial was noted.

RESULTS

Figure 2 presents the acquisition scores for all subjects. Acquisition was defined by two criteria: the number of trials prior to the first trial peck (upper panels) and by trials prior to reaching a criterion of responding on three of four consecutive trials (lower panels). Within each panel the median scores across all ITIs have been fitted by the method of least squares to a power function with negative slope. These functions account for more variance in the case of unrestrained subjects (first peck: 86%; 3 of 4: 92%) than for restrained subjects (first peck: 61%; 3 of 4: 62%).

Acquisition, as defined by each criterion, was much more rapid for restrained subjects as compared to unrestrained subjects. Averaged across all ITIs, restrained subjects required 13.1 signal-food pairings prior to the first trial peck. Unrestrained subjects averaged 43.7 pairings, $F(1,36) = 27.6$, $p < .001$. Similarly, restrained subjects averaged 19.1 pairings to reach the 3 of 4 criterion whereas unrestrained subjects required 55.1 pairings, $F(1,36) = 22.31$, $p < .001$. Indeed, there was little overlap in the acquisition scores of these two treatments at ITI values less than 192 sec. Only at the longest ITIs where acquisition without the restrainer was rapid were the two conditions similar. The effects of the restrainer were also apparent in differences in the variability of acquisition scores within each condition. Hartley's homogeneity of variance test (Winer, 1971) revealed significant differences in variability between the restrained and unrestrained conditions for each acquisition criterion: first peck: $F(18,18) = 8.69$, $p < .01$; 3 of 4: $F(18,18) = 3.15$, $p < .01$.

It can also be seen from Figure 2 that one unrestrained subject (Bird 4) at the 12-sec value did not reach the 3 of 4 criterion after producing the first trial peck. In addition, there was one instance, also at the 12-sec ITI, where a restrained subject (Bird 4) was retarded in reaching the 3 of 4 criterion (128

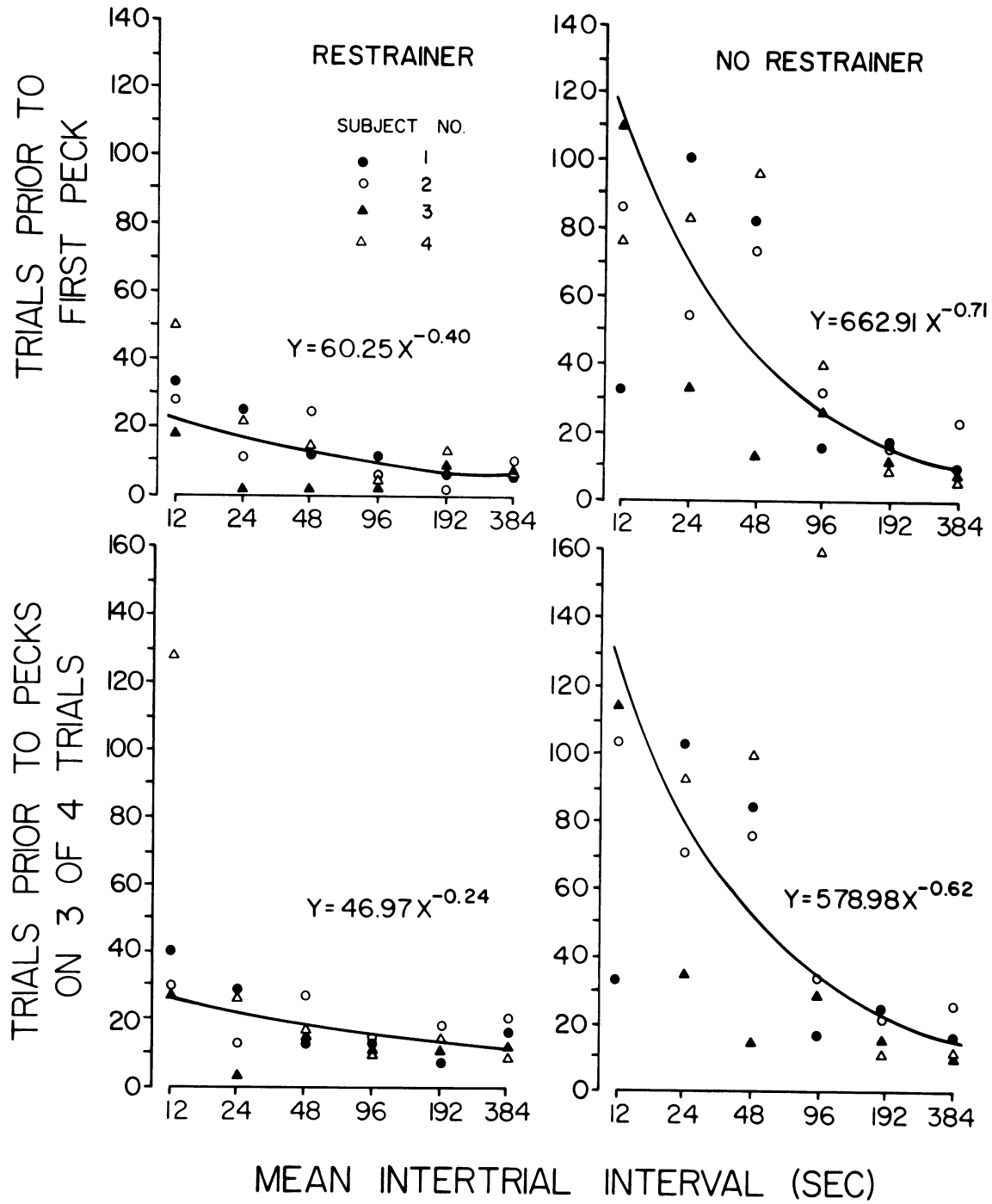


Fig. 2. Number of signal-food pairings prior to reaching two acquisition criteria for restrained (left panels) and unrestrained subjects (right panels). The first-peck criterion is presented in the upper panels; lower panels show trials prior to meeting a criterion of responding on 3 of 4 consecutive trials. Within each panel the median scores at all intertrial intervals have been fitted to power functions.

trials) after the first trial peck (50 trials). During trials this subject produced a highly stereotyped pattern of behavior consisting of bobbing its head up and down along the left side of the restrainer. This pattern was observed on 84% of the trials prior to satisfying the 3 of 4 criterion.

It should be noted that this was the only restrained subject to develop a stereotyped response pattern which was incompatible with key pecking. Invariably, other restrained subjects maintained their head at the level of the response key and within several trials began to make peck movements toward the key at signal onset. Despite this uniformity, two restrained subjects were eliminated. One restrained subject at the 384-sec ITI value emitted 133 responses during the first session, but all pecks occurred during the ITI. This subject did not respond during the next 11 sessions and was replaced. A second restrained subject, at the 48-sec ITI, was replaced for not eating on at least 50% of the trials prior to meeting the 3 of 4 criterion. One unrestrained subject was also eliminated for failure to meet this criterion.

Unrestrained subjects typically developed a pattern of behavior during trials early in training which appeared to be incompatible with key pecking. Most often, this pattern was broken rather suddenly and the subject began to weave back and forth near the key, a pattern which reliably preceded key pecking. In the extreme these early patterns persisted and signal-directed pecks did not emerge within 300 trials (12 sessions). This was the case for two subjects at the 12-sec ITI whose data are not included in the foregoing analysis. One of these subjects adopted a pattern of moving to the key area at trial onset and weaving back and forth from one side of the chamber to the other in front of the test panel. This sequence was quite like that which typically preceded acquisition in other birds and was produced reliably after only six trials within the first session. With extended training these movements were condensed. By the fourth session this bird approached the key directly at trial onset and produced minimal head-bobbing movements during trials, a pattern which persisted throughout training.

The second unrestrained subject which did not reach either acquisition criterion at the 12-sec ITI value moved to the rear of the

chamber at trial onset. At that point this subject head-bobbed and weaved along the back wall. It was again the case that this pattern was adopted within the first few trials of the first session and persisted during all 300 trials. Over the final three sessions this pattern was observed during 96% of the trials.

Not all unrestrained subjects were comparatively slow to acquire key pecking. At the 48-sec ITI, for example, Bird 3 pecked after 13 trials, equaling the median score for restrained subjects. This subject was near the key at the onset of the first trial and "air-pecked" toward the key on that trial. During the next 10 trials this subject remained near the key with its head up, a posture closely approximating the position necessitated by the restrainer.

It might be argued that the effects produced by the restrainer were not the result of the rapid association between keylight and food. Perhaps by forcing the subject to remain in close proximity to the key, the restrainer simply facilitated the pigeon's exploratory tendency to peck salient objects. If so, observation of subject's behavior during the first keylight presentation (prior to the first keylight-food pairing) might reveal differences in key-directed pecking between restrained and unrestrained subjects. On that first trial, as defined by experimenter observation, eight unrestrained subjects (including Bird 3 at 48 sec) and five restrained subjects directed pecks toward the key. The mean first-peck acquisition score for these unrestrained subjects was 21.2 as compared to 9.4 for these restrained subjects. Thus, these first-trial key-directed pecks were not engendered more frequently by the restrainer, nor were they immediately followed by key pecks on subsequent trials for either group. As a corollary, it was also not the case that the restrainer merely engendered more pecking at the key irrespective of the presence of the signal. In each condition an equal number of subjects (eight) produced their first peck during an ITI, before their first trial response.

To assess the effects of the restrainer on maintained responding subjects received five sessions of training beyond the session in which the 3 of 4 criterion was met. Figure 3 summarizes each subject's response rate during that fifth session along with the median rate for each group. There were few differ-

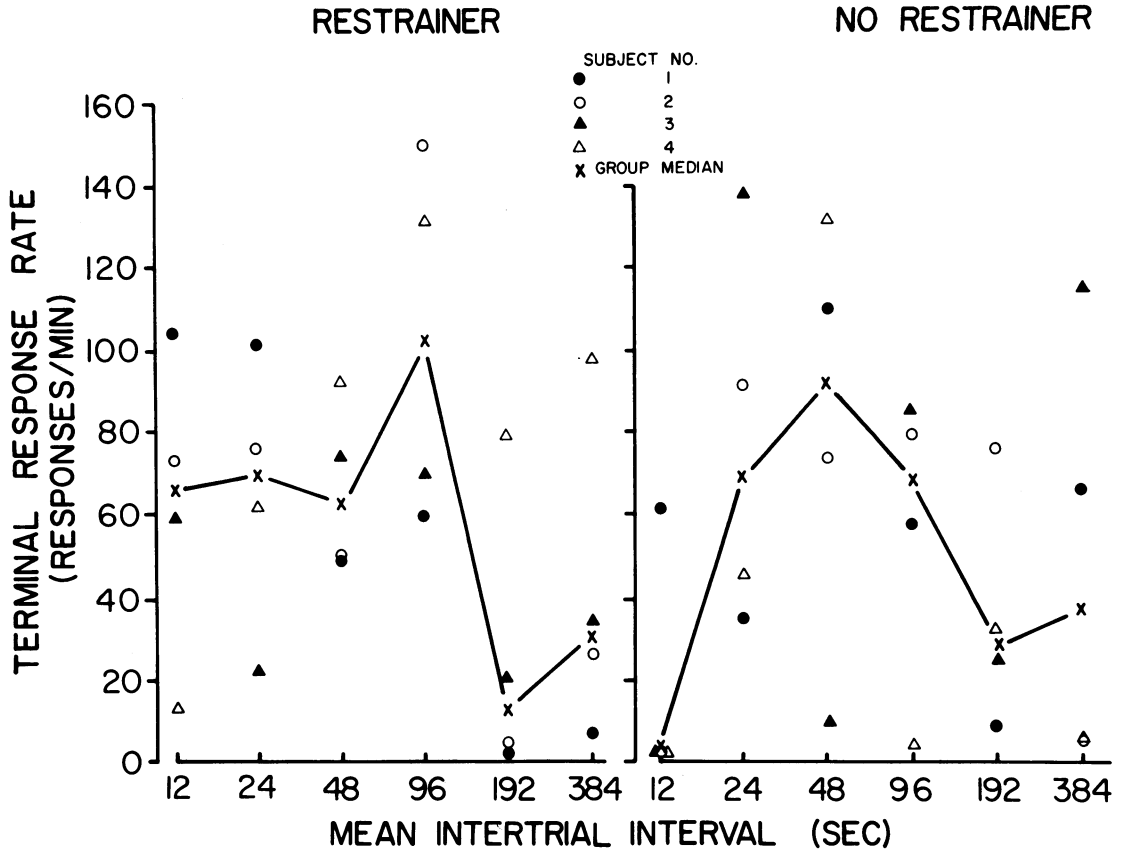


Fig. 3. Response rate for each subject during the fifth postacquisition session. Rate was computed dividing total trial responses by total trial time, including trials without a response. The function within each panel passes through the median response rate at each ITI value.

ences in response rate between restrained and unrestrained subjects, $F(1,36) = .85$, $p > .10$. The one exception may be observed at the 12-sec ITI value where three of four unrestrained subjects maintained near-zero levels of responding, whereas three of four restrained subjects produced substantial rates (i.e., greater than 60 responses/minute). There was a small overall effect of ITI on response rate, $F(5,36) = 3.34$, $p < .05$. Further analysis revealed that this effect was confined to restrained subjects, $F(5,18) = 9.62$, $p < .01$. For unrestrained subjects there was no effect of ITI on maintained rate, $F(5,18) = 1.36$, $p > .10$.

There is the suggestion of an inverted U-shaped function for both groups. An analysis of trend for restrained subjects revealed a significant linear, $F(1,18) = 7.39$, $p < .01$, and quadratic component, $F(1,18) = 11.24$, $p < .01$. However, neither component accounted for a high percentage of variance: linear = 15%;

quadratic = 24%. For unrestrained subjects only the quadratic component approached significance, $F(1,18) = 3.09$, $.05 < p < .10$, variance = 45%. The cubic component did not achieve significance for either group.

It may also be noted that the analysis of other aspects of maintained responding, such as latency or response probability (i.e., proportion of trials with a peck) revealed no differences between restrained and unrestrained subjects.

DISCUSSION

The central issue raised by these findings concerns the effectiveness of the restrainer to engender rapid acquisition and reduce variability. It is possible for several theoretical positions to suggest reasons for these effects. Contemporary analyses of conditioning, such as the Rescorla-Wagner model (1972) or Gib-

bon's scalar expectancy approach (1977), have emphasized the competition between background (i.e., contextual) stimuli and the conditioned stimulus for reinforcer value (see also Tomie, 1976). Although these approaches differ in the manner by which this competition is resolved, both would predict that reducing conditioning to uncontrolled background stimuli should facilitate acquisition. Within this framework it might, therefore, be argued that the restrainer lowered the value of contextual stimuli and facilitated the discrimination between signal-on versus signal-off periods. A related approach might argue that the restrainer reduced fluctuations in a subject's sampling of the conditioned stimulus (e.g. Estes, 1960).

From a response-centered view the restrainer might be regarded as reducing competing responses. Early work by Estes (1950) and Spence (1956) concerning the effects of restraint on learning was interpreted in this manner. A complementary position derives from recent work by Herrnstein (1970) which considers response strength to be influenced by the availability of alternative sources of reinforcement. Herrnstein's formulation has been proposed as a law of maintained responding. Yet, it is reasonable to assume that the variables affecting maintenance function similarly in acquisition.

The observational data collected in this study support the notion that the strength and nature of competing responses are related to speed of acquisition for unrestrained subjects. These subjects were observed to adopt a stereotyped pattern of responding during the signal quite early in training, often within the first few trials. Most of these responses, such as pecking the ground in the corner of the chamber, were incompatible with key pecking (see also Brown & Jenkins, 1968).

It is useful to compare these observations of unrestrained subjects to those made by Staddon and Simmelhag (1971) who carefully monitored pigeons' behavior under a variety of food-delivery schedules. Their analyses indicated that behavior patterns during interfood intervals may be divided into two types: interim responses, which occurred during periods when food was not expected and were quite variable across different subjects; and terminal responses, those occurring in close temporal proximity to food, which were highly stereo-

typed in all birds and consisted of consumatory-like responses, i.e., pecking in the case of pigeons and food reinforcers. These authors noted that early in training the terminal response differed across subjects. However, with little exception, at some point during training there was a sudden shift by all subjects to pecking as the terminal response. Thereafter little change was noted. One of these subjects (Bird 49), for example, consistently placed its head in the food magazine as the terminal response during the first seven sessions. During the eighth session this subject's terminal response suddenly shifted to pecking the magazine wall.

These observations are similar to those made during signal presentations early in training for unrestrained subjects. Viewed in this manner the restrainer might be thought to block the occurrence of interim behavior. Perhaps interim behavior is the source of competing responses early in training, that is, before interfood intervals are initially timed and stable terminal responding emerges. Further, to the extent that interim and terminal responses are reciprocally inhibitory (e.g., Frank & Staddon, 1974; Hinson & Staddon, 1978), the restrainer may facilitate the emergence of appropriate terminal behavior.

Each of the theoretical positions discussed, ranging from response-centered to cognitively oriented accounts, can accommodate the effects of the restrainer. Yet, these data force important constraints on each interpretation. For example, the sudden shift to a consumatory-like terminal response, noted in this study as well as Staddon and Simmelhag's work, seems to rule out a straightforward application of the law of effect as a description of this transition. Prior to this shift, various responses incompatible with key pecking were adventitiously reinforced. This shift occurred despite these unprogrammed response-reinforcer relations.

Moreover, regardless of the theoretical perspective adopted it would appear hazardous to attempt a universal characterization of the influence of ITI on acquisition, at least within the range of ITI values here studied. For unrestrained subjects ITI exerted strong control over acquisition, a finding consonant with earlier work (i.e., Terrace et al., 1975; see also Gibbon et al. 1977). However, for restrained subjects ITI exerted weaker control. Further,

it is not clear that a power function provides a suitable first-approximation fit of the acquisition data for restrained subjects. In this way, these data are consistent with earlier suggestions concerning the foolhardiness of postulating general curves of learning (e.g., Skinner, 1950).

These findings also bear on the recent claim that speed of acquisition serves as the assay of an organism's biological predisposition to associate certain classes of events with each other (e.g., Seligman, 1970). Unfortunately, judging from the functions in Figure 2, one would be led to quite different conclusions regarding the "preparedness" of the pigeon's key peck depending upon whether the data from restrained or unrestrained subjects were thought to be representative. Perhaps rapid learning may be achieved either by utilizing phylogenetically based associations or by optimizing the learning environment.

These observations illustrate the difficulties inherent in using variations in protean measures such as acquisition to indicate important theoretical distinctions. Doubtless, fluctuations in these variables may depend as much upon procedural considerations as upon the operation of invariant underlying mechanisms.

The effects of the restrainer were specific to acquisition. Maintained responding showed little influence on the restrainer with the exception of short ITI values where stable key-directed responding may not be reliably observed in unrestrained subjects. In previous work somewhat higher response rates have been observed for restrained as compared to unrestrained subjects in differential-reinforcement-of-low-rate (DRL) schedules (Richardson & Loughhead, 1974; Skuban & Richardson, 1975). Of course higher rates in this procedure generally covary with lower rates of reinforcement. It may be that under schedules requiring temporally spaced responding, such as DRL, the availability of interim (i.e., collateral) behavior is important for effective performance (cf. Frank & Staddon, 1974).

As variable-interval schedules place no similar restriction on response rate, differences in maintained responding between restrained and unrestrained subjects might be expected to be reduced or eliminated (cf. however, Skuban & Richardson, 1975, who note a relationship between test chamber size and VI rate). It should also be noted that during the final session

unrestrained subjects were observed to approach the key quickly at signal onset and adopt positions similar to restrained subjects during the remainder of the trial. Accordingly, one might expect less influence of restraint on maintained responding as compared to acquisition.

For both restrained and unrestrained subjects, the function relating ITI to mean terminal rate was roughly, though incompletely, approximated by a quadratic fit. Terrace et al. (1975) found that maintained responding was well described by a power function with positive slope. However, Griffin (1974), in an unpublished parametric autoshaping study of ITI effects in pigeons and rats, noted an inverted U-shaped function similar to that suggested by the present data. Yet another result has been reported by Gibbon et al. (1977) in a parametric study using pigeons in which a wide range of trial durations (2 sec to 64 sec) were factorially combined with ITI values ranging from 7 sec to 768 sec. While the ratio of ITI to trial value was the best predictor of acquisition, maintained responding reflected the influence of absolute trial value more than ITI or the ratio of these parameters.

It is not apparent what variables are responsible for these diverse results. The present work studied maintained responding for fewer postacquisition sessions than did previous studies. Gibbon et al. continued subjects for 375 trials beyond reaching a 3 of 4 criterion. Terrace et al. studied response maintenance for an average of 250 trials beyond the first trial peck, whereas Griffin used 600 total conditioning trials. Unfortunately, it is not clear that the variations in maintained responding reported in these latter studies are explicable by differences in length of training. That is, although these studies assayed response rate after different amounts of training, there is no evidence to suggest that the function relating ITI to rate should change in form during extended training.

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